TAUOLA Fixed For ALPGEN+HERWIG

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Context

- Long-standing problem in CDF TAUOLA interface when using ALPGEN+HERWIG
- What TAUOLA and interface are supposed to do:
  - Take events from hard process generators (e.g. PYTHIA or ALPGEN) with or without showering (e.g. HERWIG)
  - Remove all descendants of taus
  - Re-decay taus with proper polarization and kinematics
  - τ polarization assignments are made for decays from Higgs, W, and Z; All others are assigned a “random” polarization (some details on next slide)
- This has worked fine for PYTHIA+TAUOLA, but has been broken for ALPGEN+TAUOLA

Polarization Assignment

- If τ is from Z, W, or Higgs:

  Polarization is either along or opposite τ momentum in τ mother's rest frame, depending on chirality

- Otherwise:

  Polarization is either along or opposite τ momentum in lab frame, depending on chirality

- Chirality is assigned based on mother's particle type

	Chirality		Prob.
	τ^+	τ^-	
h^0, H^0, A^0	+1 -1	+1 -1	0.5 0.5
$H^\pm$	-1	+1	1.0
$W^\pm$	+1	-1	1.0
Z^0/γ^*	+1 -1	-1 +1	P_z $1-P_z$
All others	+1 -1	+1 -1	0.5 0.5

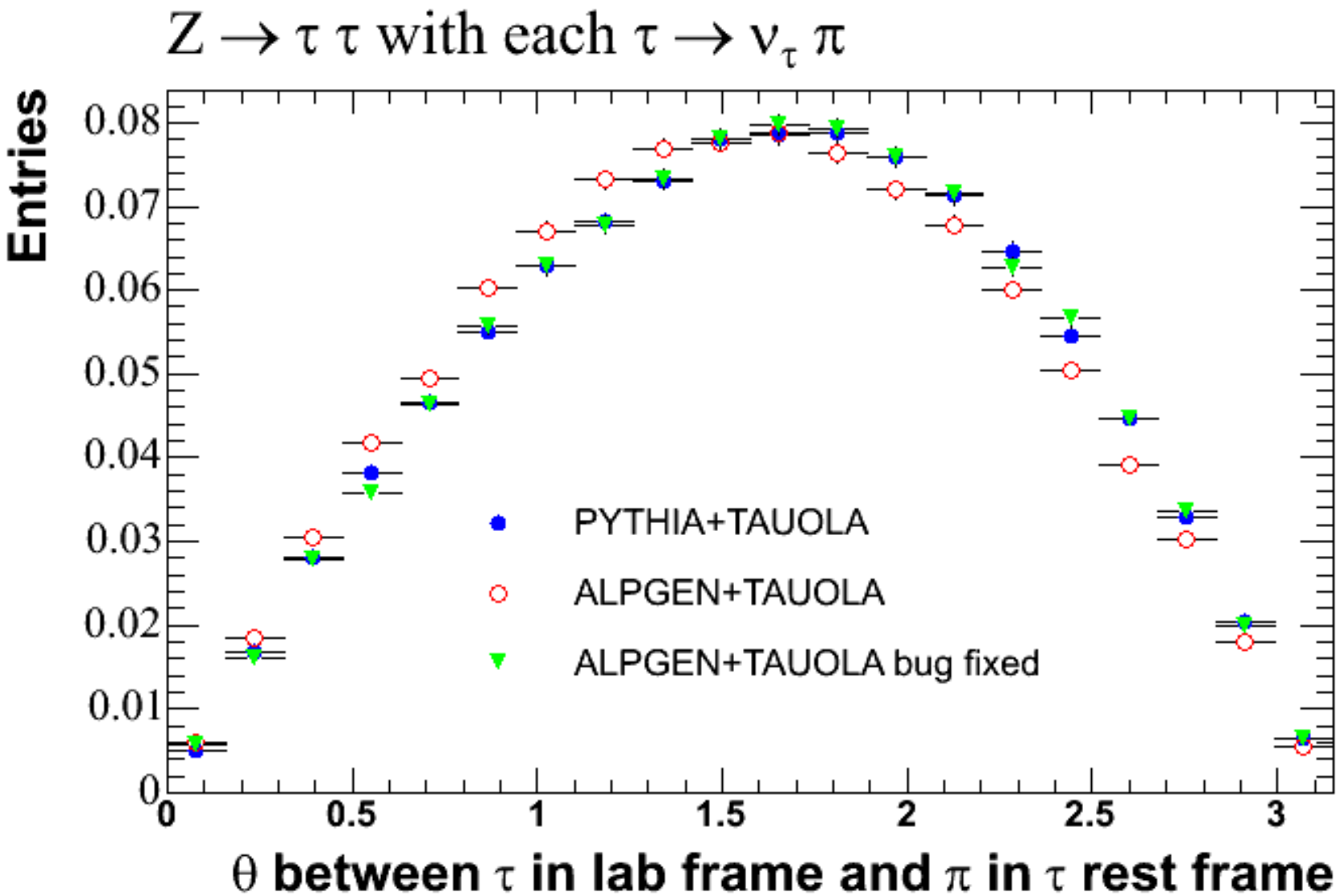
From CDF note 5719, J. Kim, T. Moulik, P. Murat, "CDF Run II Interface to TAUOLA..."

P_Z = function of s and τ scattering angle

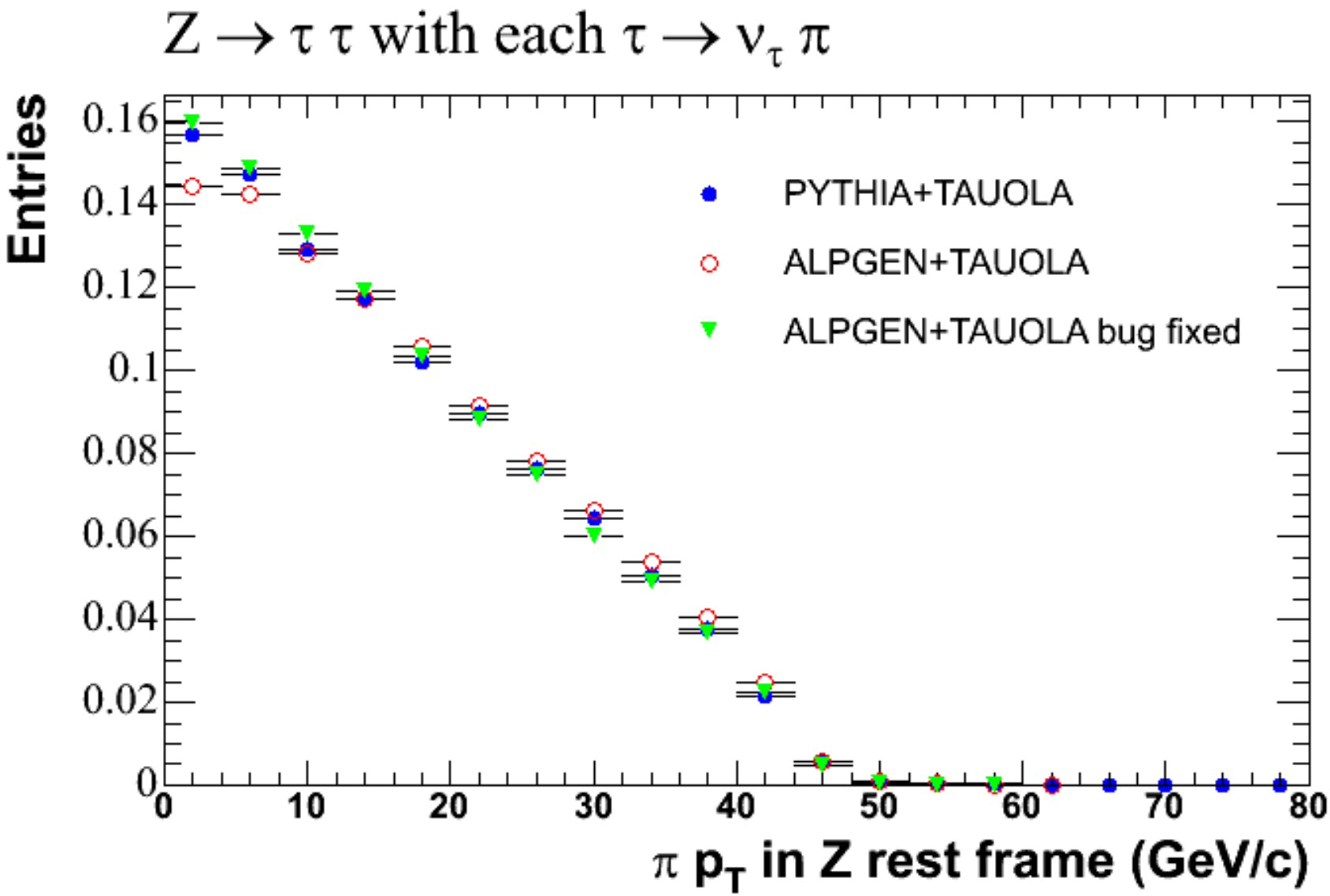
Validation Samples

- Generated 18 samples for performing validation:
  - 30k events each of
    - $Z^0 \rightarrow \tau^+\tau^-$, with $\tau \rightarrow \nu_\tau\ \nu_e\ e$
    - $Z^0 \rightarrow \tau^+\tau^-$, with $\tau \rightarrow \nu_\tau\ \nu_\mu\ \mu$
    - $Z^0 \rightarrow \tau^+\tau^-$, with $\tau \rightarrow \nu_\tau\ \pi$
    - $Z^0 \rightarrow \tau^+\tau^-$, with $\tau \rightarrow \nu_\tau\ \rho\,(\pi\pi^0)$
    - $Z^0 \rightarrow \tau^+\tau^-$, with $\tau \rightarrow \nu_\tau\ a_1(2\pi\pi)$
  - Using each of the following:
    - PYTHIA (6.216) + default TAUOLA from 5.3.3
    - ALPGEN (1.3.3) + HERWIG (6.400) + default TAUOLA from 5.3.3
    - ALPGEN (1.3.3) + HERWIG (6.400) + bug-fixed TAUOLA
  - For PYTHIA: generated with Z invariant mass > 75 GeV/c^2
  - For ALPGEN: generated with $50 < m(\tau^+,\tau^-) < 130$ GeV/c^2 and zero additional partons

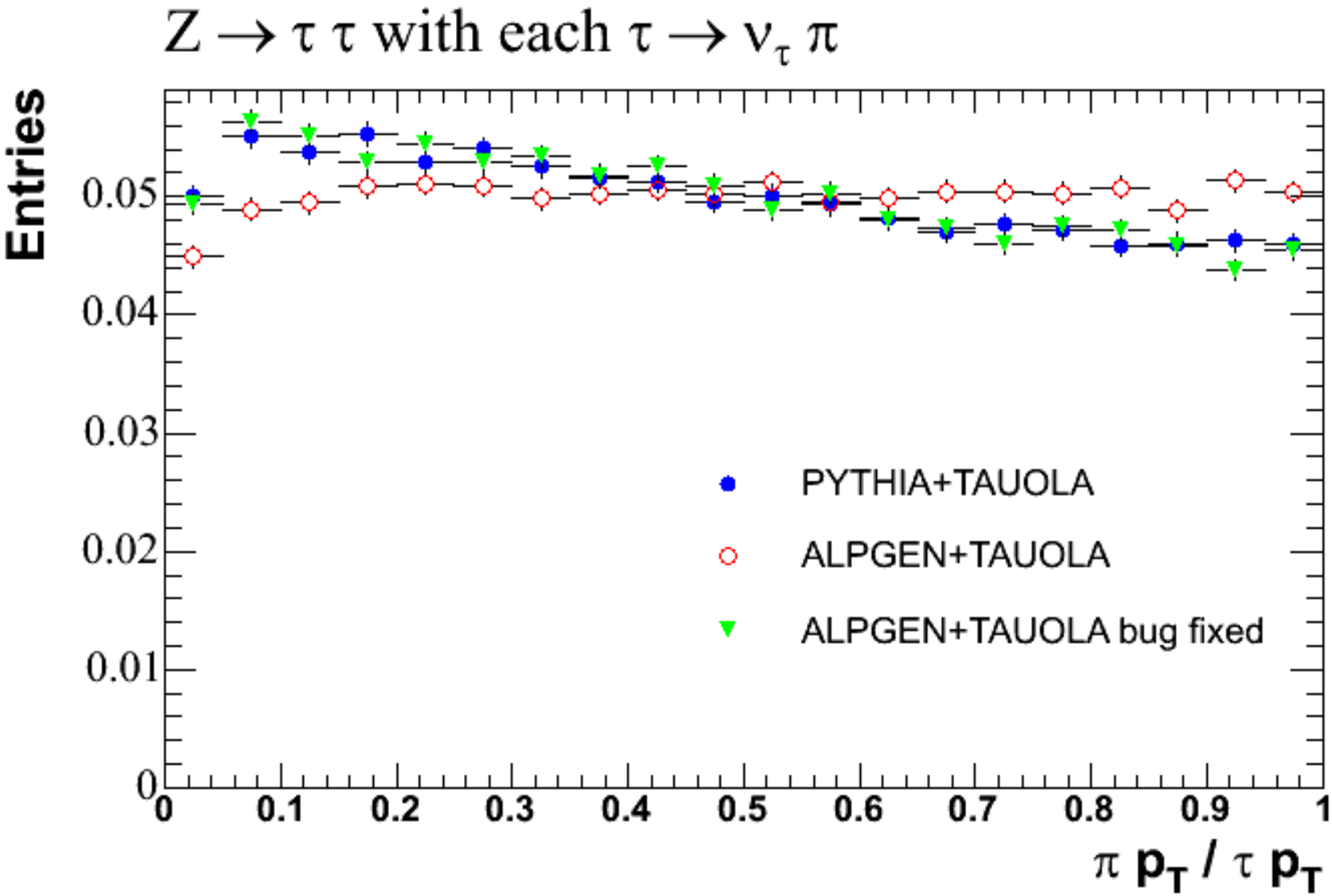
Angular Distribution of π from τ



p_T Spectrum of π from τ

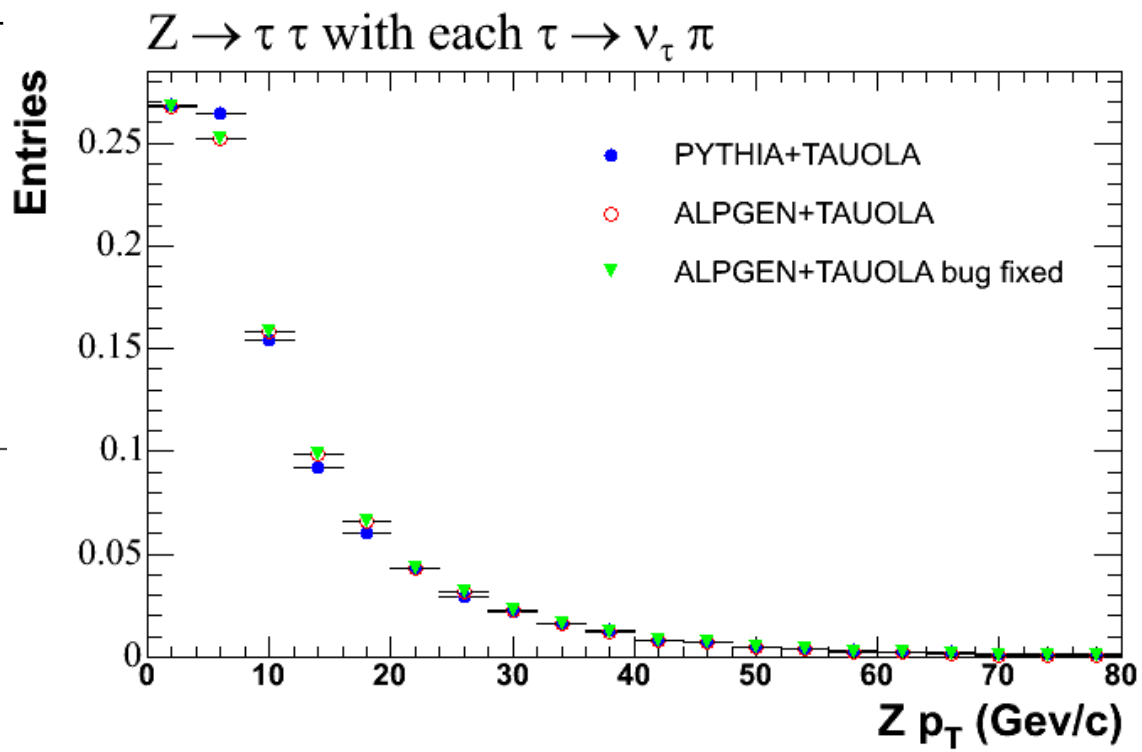


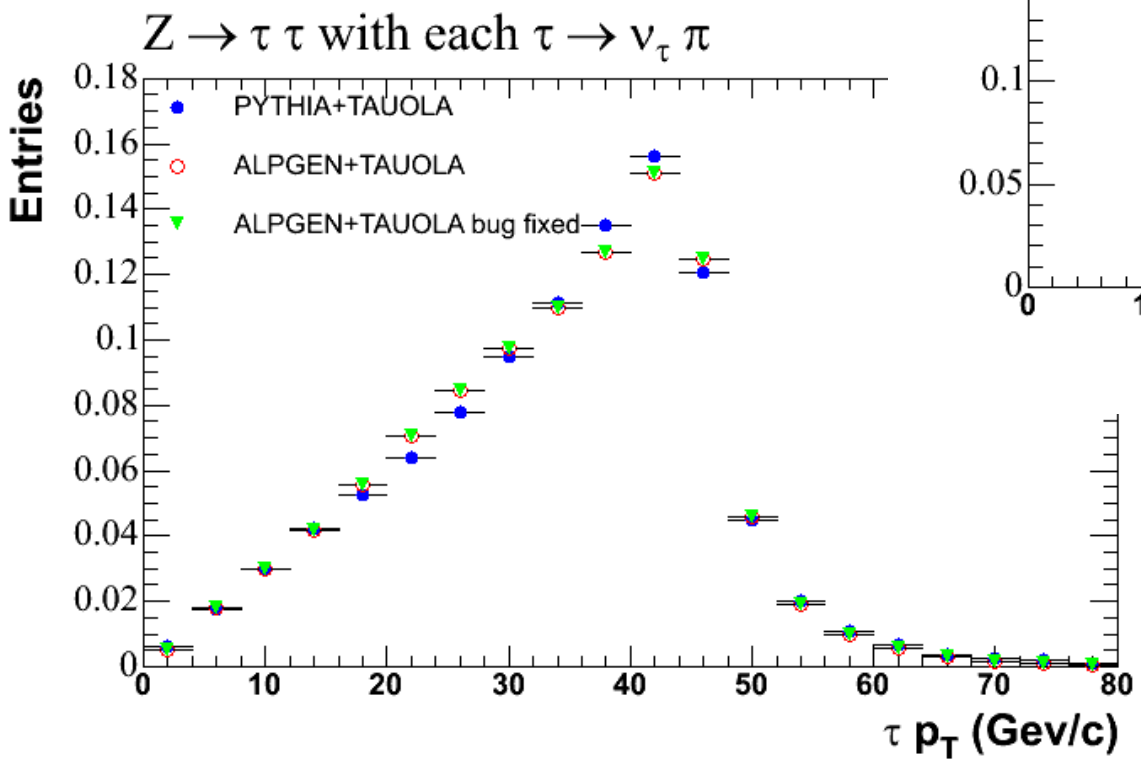
Transverse Momentum Ratio



Z and τ Transverse Momenta

- Z p_T and τ p_T are unchanged by the bug fix
- PYTHIA vs. ALPGEN differences, not TAUOLA





The Culprit

- Differences in HepEvt format between PYTHIA and ALPGEN

PYTHIA:

I	particle/jet	ISTHEP	IDHEP	JMOHEP		JDAHEP		PHEP(1,I)	PHEP(2,I)	PHEP(3,I)	PHEP(4,I)	PHEP(5,I)
1	!p+!	3	2212	0	0	0	0	0.00000	0.00000	979.99955	980.00000	0.93827
2	!p~-!	3	-2212	0	0	0	0	0.00000	0.00000	-979.99955	980.00000	0.93827
3	!u~!	3	-2	1	0	0	0	-0.16195	0.27338	129.68924	129.68963	0.00000
4	!g!	3	21	2	0	0	0	-0.75912	-0.67408	-190.70013	190.70283	0.00000
5	!u~!	3	-2	3	0	0	0	-0.15885	0.26816	127.21168	127.21207	0.00000
6	!u!	3	2	4	0	0	0	-0.40287	-2.65466	-16.06550	16.28834	0.00000
7	!Z0!	3	23	5	6	0	0	-0.56172	-2.38650	111.14618	143.50040	90.73523
8	!tau-!	3	15	7	0	0	0	42.05012	14.59669	48.76820	66.05127	1.77700
9	!tau+!	3	-15	7	0	0	0	-42.61184	-16.98319	62.37798	77.44913	1.77700
10	(Z0)	2	23	7	0	11	12	-0.56172	-2.38650	111.14618	143.50040	90.73523
11	(tau-)	2	15	8	0	31	33	42.05012	14.59669	48.76820	66.05127	1.77700
12	(tau+)	2	-15	9	0	34	36	-42.61184	-16.98319	62.37798	77.44913	1.77700
13	(Delta+)	2	2214	1	0	37	38	0.60051	-0.04788	382.83036	382.83290	1.25605
14	(u~)	2	-2	4	0	39	39	1.26614	2.33661	-7.67462	8.12844	0.33000

ALPGEN:

I	particle/jet	ISTHEP	IDHEP	JMOHEP		JDAHEP		PHEP(1,I)	PHEP(2,I)	PHEP(3,I)	PHEP(4,I)	PHEP(5,I)
1	!p+!	101	2212	0	0	0	0	0.00000	0.00000	980.00000	980.00000	0.93827
2	!p~-!	102	-2212	0	0	0	0	0.00000	0.00000	-980.00000	980.00000	0.93827
3	!!	103	0	1	2	0	0	0.00000	0.00000	0.00000	1960.00000	1960.00000
4	!d!	121	1	6	5	7	5	0.00000	0.00000	146.01100	146.01100	0.00000
5	!d~!	122	-1	6	4	11	4	0.00000	0.00000	-14.25400	14.25400	0.00000
6	!Z0!	120	23	4	4	16	16	0.79652	0.09753	131.72400	160.26700	91.28800
7	!gen. code!	141	94	4	6	9	10	3.78560	1.07286	146.92100	145.40700	-21.40270
8	!!	100	0	4	5	0	0	0.84770	-0.53048	0.87772	1.33056	0.00000
9	(g)	2	21	7	10	21	22	-3.78560	-1.07286	4.53997	6.05439	0.75000
10	(uu_1)	2	2203	7	13	23	22	0.00000	0.00000	828.53800	828.53800	0.29480
11	!gen. code!	142	94	5	6	13	15	-2.98908	-0.97533	-15.19730	14.85930	-4.47719
12	!!	100	0	5	4	0	0	-0.94578	-0.32482	2.03144	2.26423	0.00000
13	(d)	2	1	11	14	24	23	1.25692	-0.10591	-2.42691	2.75379	0.32000
14	(u~)	2	-2	11	15	25	24	1.73216	1.08124	-185.85200	185.86300	0.32000
15	(ud_0~)	2	-2101	11	21	26	25	0.00000	0.00000	-776.52300	776.52400	0.36253
16	!Z0!	155	23	4	5	17	18	0.79652	0.09753	131.72400	160.26700	91.28800
17	!tau-!	123	15	16	17	19	17	10.87320	-44.14280	73.29190	86.26510	1.77700
18	!tau+!	124	-15	16	18	20	18	-10.07660	44.24030	58.43210	74.00140	1.77700
19	!tau-!	195	15	17	16	92	94	10.87320	-44.14280	73.29190	86.26510	1.77700
20	!tau+!	195	-15	18	16	95	97	-10.07660	44.24030	58.43210	74.00140	1.77700
21	!d~!	158	-1	7	22	59	38	-2.42772	-0.79858	2.85351	3.84402	0.32000
22	!d!	158	1	7	33	51	21	-0.21060	-0.03762	0.87570	0.95657	0.32000

Conclusions

- Repaired and validated the TAUOLA interface code so that it properly handles ALPGEN+HERWIG
- The sample $Z^0 \rightarrow \tau^+\tau^-$, with $\tau \rightarrow \nu_\tau\ \pi$, shows the effect most clearly, but also seen in some others (not shown)
- Generated handful of $W \rightarrow \tau\ \nu$ decays to see that TAUOLA now recognizes them as well
- Verified that PYTHIA result is unchanged by the new code
- Plan:
  - Get bug-fixed version into future CDF releases
- Potentially impacts anyone using Z, W, or Higgs decays to τ 's, for their signal or background studies

backup slides:

Details of Z^0/γ^* Chirality

$$P_Z(s,\theta) = \frac{\frac{d\sigma_{Born}}{d\cos\theta}(s, \cos\theta\,;\,1)}{\frac{d\sigma_{Born}}{d\cos\theta}(s, \cos\theta\,;\,1) + \frac{d\sigma_{Born}}{d\cos\theta}(s, \cos\theta\,;\,-1)}$$

$$\frac{d\sigma_{Born}}{d\cos\theta}(s, \cos\theta\,;\,p) = (1 + \cos^2\theta)F_0(s) + 2\cos\theta\, F_1(s) - p[(1+\cos^2\theta)F_2(s) + 2\cos\theta\, F_3(s)]$$

s = center-of-mass energy

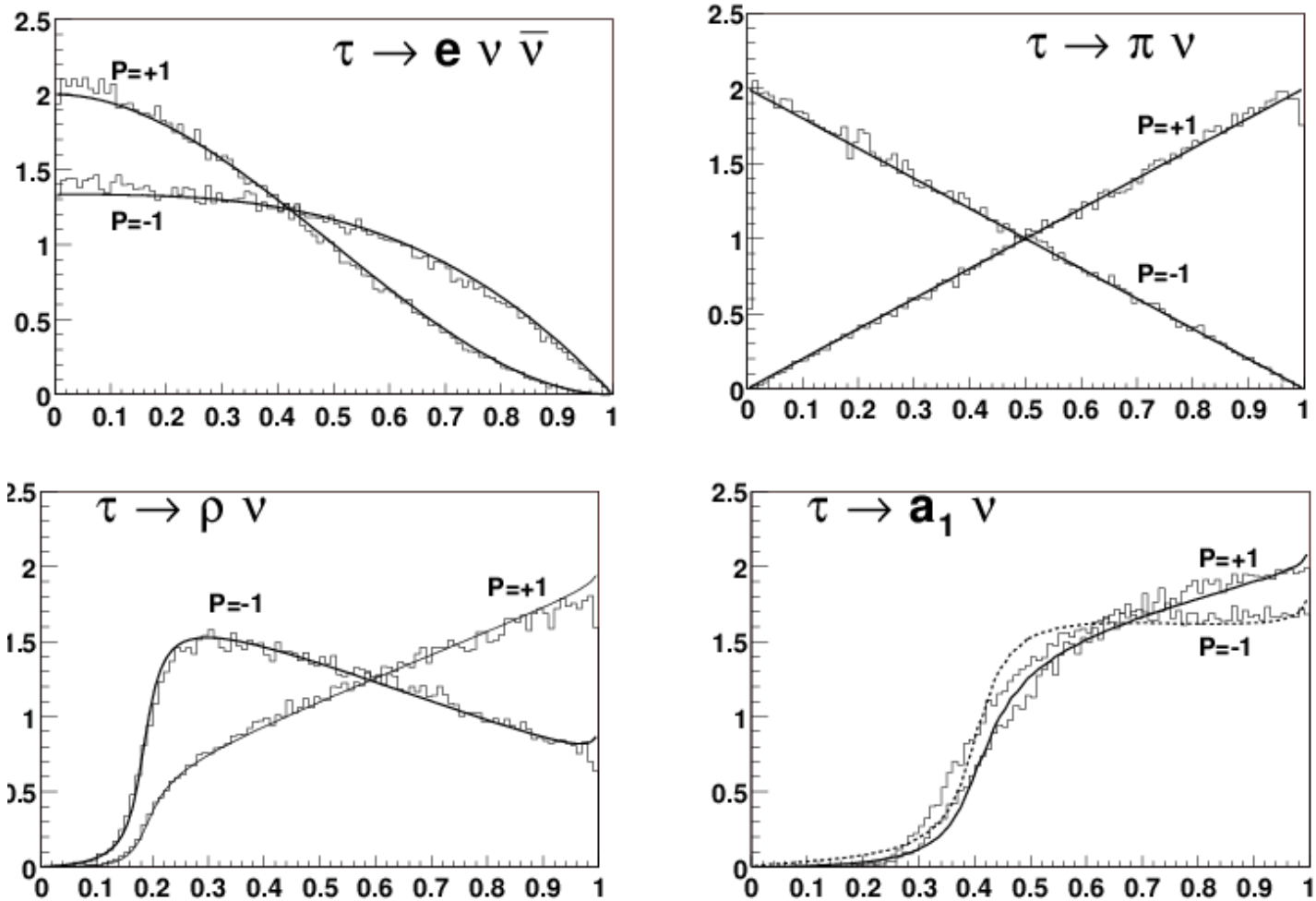
θ = scattering angle of τ in Z rest frame

F_0, F_1, F_2, F_3 = form factors

From CDF note 5719, J. Kim, T. Moulik, P. Murat,
"CDF Run II Interface to TAUOLA..."

p_T Ratios (daughter p_T / τ p_T)

- PYTHIA+TAUOLA agrees with theoretical curves
- … and now ALPGEN agrees with PYTHIA (averaged over P)



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